A PRACTICAL COURSE

OF

GENERAL PHYSIOLOGY

FOR MEDICAL STUDENTS

BY

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AND

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SECOND EDITION

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PREFACE.

The objects of this Course are twofold—First, to train the student in the investigation of the many problems of medical science which he has afterwards to face, and to teach him to observe, record, and describe the vital phenomena with which he has to deal.

Second, to give him a real and sound practical foundation to his after study of Physiology, based upon his personal experience and not upon the dicta of his teacher and text books.

For this reason the problems to be investigated and the method of investigation are indicated, but the results to be obtained and the conclusions to be drawn are left to the student, who must before all be taught to observe and to experiment without preconceived ideas and without any anticipation of a particular result, but with a mind open to accept whatever result may be obtained, and from that result to attempt the solution of the problem under investigation.

The Course should be taken along with a Course of Lectures and Demonstrations, and it should be so arranged that in each part the practical work precedes the lectures.

September, 1908.

The present Edition has been almost entirely re-written and re-arranged in the light of the experience of the working of the class of General Physiology during the past three years.

September, 1911.

PRELIMINARY.

THROUGHOUT this Course the student must keep careful records of every experiment he performs. When apparatus is used he must make diagrams of its arrangement, and when tracings are taken these must be fixed and preserved.

Before beginning any experiment he must first clearly understand its *object*, and no student will be allowed to continue an experiment who has not entered in his note book the question to be investigated.

He must also before starting understand the *method* adopted and how it will throw light upon the question.

While carrying out the experiment he must not confine his attention to the main *result*, but must observe everything which happens and record for further investigation anything he does not understand. The experiment must be carried through without any preconceived idea of what the results should be, and *from the results obtained* an attempt must be made to draw *conclusions* and to give an answer to the question which is under investigation.

In every experiment the student must record :

1. Object.
2. Method.
3. Results.
4. Conclusions.

Every student must be provided with a large note book, pencil, strong sharp-pointed scissors, strong dissecting forceps, and a camel's hair brush.

I. THE ESSENTIAL NATURE OF LIVING MATTER IN ITS SIMPLEST FORM.

1. Object.—To learn something of the essential nature of living matter (protoplasm).

2. Methods.—Take a very simple form of living matter—the yeast plant—and place it under various conditions. Place a small quantity on a slide, and add a drop or two of water. Rub up into an emulsion with a glass rod, and transfer a few drops on the end of the rod: (A) to a test-tube of a solution containing the chemical elements in the yeast—urea $CO(NH_2)_2$, glucose $C_6H_{12}O_6$, with traces of sodium phosphate Na_2HPO_4, potassium sulphate K_2SO_4, and calcium phosphate $Ca_3(PO_4)_2$; (B) to a test-tube filled with water.

See that the tubes are quite full. Shake well and examine a drop with the microscope, and make a rough estimate of the number of torulæ in two or three fields of the microscope. Draw one or two.

On each bench—

Students at places 1 and 2 at once insert the corks firmly into the tubes. The tubes of 1 are placed in an incubator at 37° C. The tubes of 2 are placed in a vessel of broken ice.

Students at place 3 introduce a few drops of phenol solution, insert the cork, and place the tubes in the incubator.

Students at place 4 boil the tubes before quite filling them, cool them under the tap, fill them with water, insert the corks, and place them in the incubator.

3. Results. A. On Yeast.—Next day the tubes are to be examined with the naked eye before and after shaking and the condition of each tube studied, contrasting it with the condition on the previous day. A drop of the fluid is to be examined with the microscope, again estimating the number of torulæ in two or three fields of the microscope. The students

at each bench should make a combined table of their results as to gas-formation, change in opacity and change in number of torulæ, using + and – as signs.

		Gas.	Opacity.	Number.
Tubes with sugar (1) at -	37°C.			
(2) at -	0°C.			
(3) with	Phenol			
(4) -	Boiled			
Tube with Water at -	37°C.			

B. On Fluid.—(*a*) *Disappearance of Sugar.* Boil the original solution (A) and the solution after incubation (B) for some time with phenylhydrazine and acetic acid to demonstrate the presence of glucose.

A. Note abundant glucosazone crystals.

B. Note diminution or absence of glucosazone.

(*b*) *Formation of Alcohol.* To about half an inch of the fluid add about half an inch of strong sulphuric acid and warm to boiling. Then run in a solution of potassium bichromate and note the change of colour produced by the reducing action of the alcohol.[1]

(*c*) *Nature of Gas evolved.* With a fine pipette add KHO dissolved in alcohol to a Doremus ureameter in which the solution has been incubated with yeast, and note the absorption of the gas evolved—CO_2.

4. Conclusions.—(1) What has happened to the yeast in each of the tubes ?

(2) What conclusions do you come to as to the influence of the various conditions to which it has been subjected upon the yeast protoplasm ?

(3) How has the growth of the yeast taken place ?

(*a*) Where does yeast protoplasm get material for growth ?

(*b*) Where does yeast protoplasm get energy for growth ?

[1] The yeast must be alcohol free.

II. MUSCLE-NERVE.

I. What is the effect of an electric current on the endings of nerves in the skin?

Methods.—A. *Simple Galvanic Current.* Connect thick covered wires with the terminals on the table marked *G*, + for positive and – for negative, from the constant current supplied at about 15 volts from a dynamo. Insert into the circuit a mercury key, as shown in the diagram, so that when it is closed the current will flow through the terminals (fig. 1). Hold the ends of the wires between the moistened finger and thumb, and note the sensations produced when the current is allowed to pass by closing the key, when it is cut out or broken by

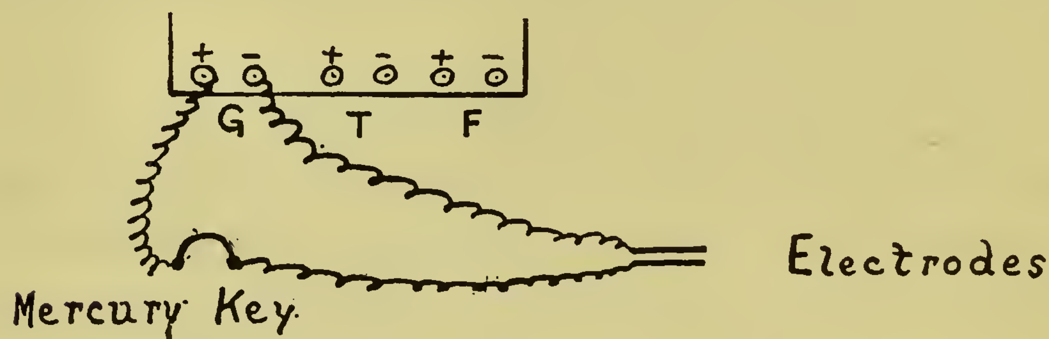

Fig. 1.—Simple Galvanic Current.

opening the key, and when the current is flowing. Repeat, holding the wires upon the tongue. Note whether the sensations are different or similar at the two poles on closing and on opening.

B. *Induced Current.* Instead of using the galvanic current direct, insert an induction coil into a circuit made by connecting two wires with the terminals from the dynamo marked *F* (fig. 2).

Introduce a mercury key into the circuit, and connect the ends of the wire with the screws on the top of the primary circuit of the induction coil as shown in the diagram. Lead wires from the terminals of the secondary coil to a friction key so that when it is closed the current is short circuited. Lead

off two terminal wires from the key. Pull the secondary coil well away from the primary, open the friction key and use the wires from it as in last experiment. Note the effect on the tongue of the sudden appearance and disappearance of the current induced in the secondary coil each time the primary circuit is made or broken.

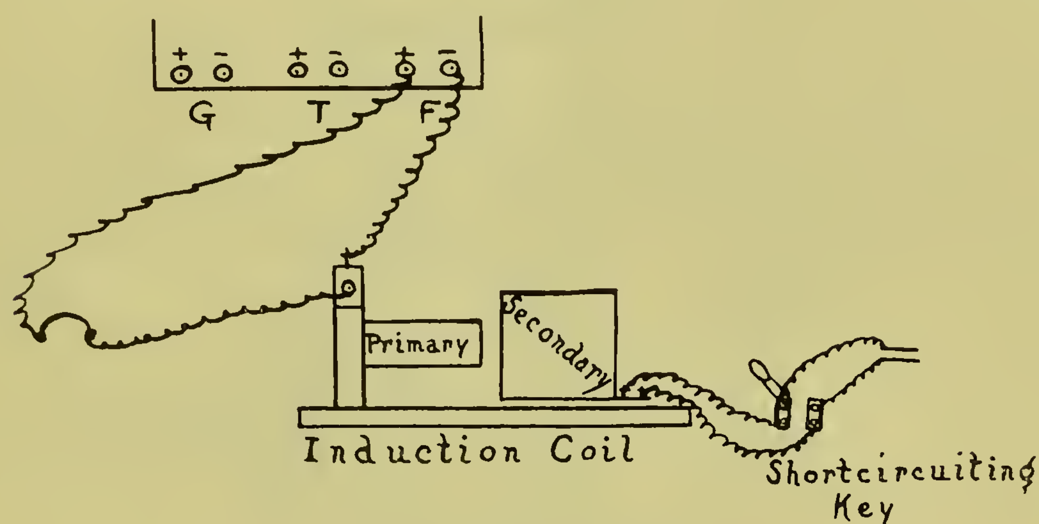

FIG. 2.—Induced Current.

RESULTS.—Taking sensation as the index of stimulation, record the results of the sudden making and breaking of the electric current, and of its continuous flow on the table below.

Make.	Flow.	Break.

C. *Rapid Series of Induced Currents.* Connect up an induction coil with the electric current, using the terminals at the *end* of the coil so as to introduce the Neef's hammer (fig. 3), and introducing a mercury key into the primary circuit and a friction key into the secondary circuit as before (fig. 2).

Note that when the mercury key is closed the current passes round the electro-magnet, which pulls down the spring and hammer and thus breaks the contact at the screw in the middle of the spring. The current is interrupted, the magnet

demagnetized and the spring bounds back. The number of interruptions depends on the length of the spring.

Open the friction key and pull the secondary coil well away from the primary and apply the wires to the tongue. Close

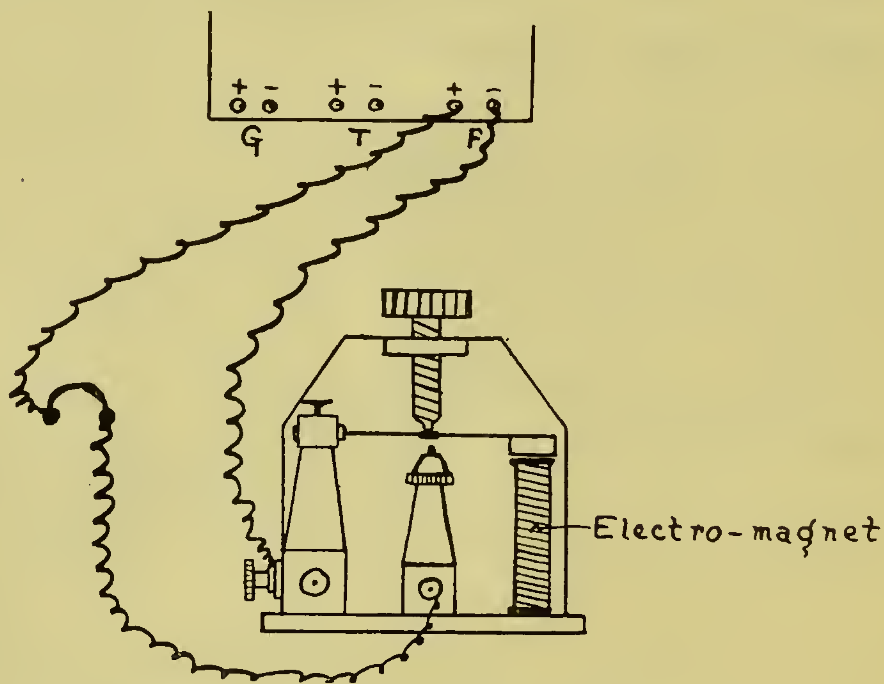

FIG. 3.—End of Coil showing Neef's Hammer.

the mercury key, and if no sensation is experienced push the secondary coil nearer to the primary. Record the resulting sensation.

II. What is the Influence of the Brain and the Spinal Cord on Skeletal Muscle.

METHOD.—Study the attitude, movements, and the effect of touching, and of turning the animal on its back ; (1) *in a frog with the brain and spinal cord intact* ; (2) *in a frog with the brain destroyed.*

Holding the frog by its hind legs, kill it by a stroke of its head upon the edge of the table, and cut off its head behind the tympanic membranes.

After a few minutes, study the attitude, movements, and the effect of touching and pinching. Feel the condition of the muscles as to consistence, and place the animal on its back.

(3) *In a frog with the brain and spinal cord destroyed.* Pith the frog by passing a thick pin down the vertebral column so as to destroy the spinal cord (fig. 4). Note carefully

FIG. 4.—Pithing Frog.

anything that takes place in the muscles as this is done. Study the frog again as to attitude, movements, effect of touching and pinching. Examine the consistence of the muscles.

CONCLUSIONS.—What is the influence of

(*a*) The brain, and

(*b*) The spinal cord upon the muscles ?

III. What is the Influence of the Nerves upon Skeletal Muscles ?

METHODS.—(A) Stimulation of the nerve, and (B) throwing nerve out of action.

The second frog supplied has been killed by destroying its brain. A ligature has then been placed round all the structures

FIG. 5.—Incisions for Separation of Hind Legs.

of one leg excepting the sciatic nerve, and a dose of curare has been injected under the skin.

Compare the condition of this frog with the normal one before the cord was destroyed.

What has been the effect of the curare ?

Remove the anterior part of both frogs by three cuts (fig. 5). Skin the hind legs and dissect out the sciatic

nerve in the thigh (figs. 6 and 7). Pinch the nerve in each leg of the normal and of the curarised frog, and record your results.

Fig. 6.—Skinning Hind Legs (use cloth round fingers).

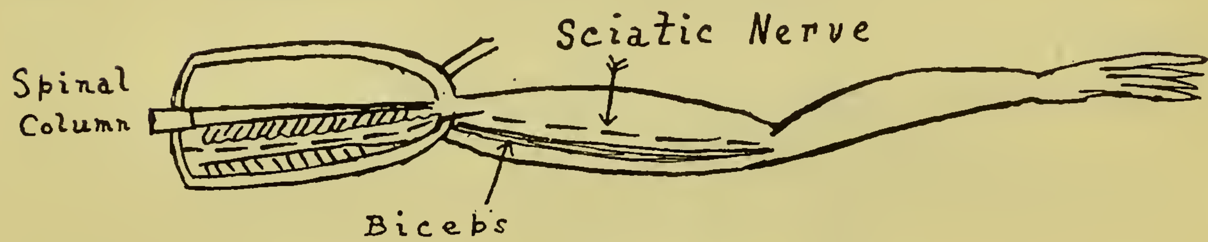

Fig. 7.—Dissection of Sciatic Nerve.

Connect up a galvanic circuit as in fig. 1, using the pin electrodes provided.

Apply the electrodes to the structures indicated below, and by closing and opening the key, stimulate.

Result.—Normal frog, (*a*) Sciatic nerve.
(*b*) Gastrocnemius muscle.

Curarised frog, 1. Limb exposed to curare (unligatured).
(*a*) Sciatic nerve.
(*b*) Gastrocnemius muscle.
2. Limb protected (ligatured).
(*a*) Sciatic nerve.
(*b*) Gastrocnemius muscle.

Record the results on the appended table:

	Normal.	Curarised.	Protected.
Nerve - -			
Muscle - -			

CONCLUSIONS—

1. What is the influence of nerve upon skeletal muscle ?
2. What is the influence of curare upon nerve, muscle, and the junction of nerve with muscle ?
3. Can a muscle be stimulated without the intervention of nerve ?

IV. What is the effect of an Electric Current upon Nerve and Muscle ?

A. On the Isolated Nerve Muscle.

I. GALVANIC CURRENT.

Study the galvanic stimulation of nerve and muscle as in I. A, p. 8, using the normal muscle-nerve preparation already made, and increasing the strength of the current by moving the handle on the switch-board from *W* to *S*. Record any difference you may observe at making and at breaking the current.

II. INDUCED CURRENT.

Fit up an induction coil for single induction shocks and bring the electrodes upon the gastrocnemius muscle. With the secondary coil well out from the primary, make and break the primary circuit again and again, moving the secondary coil nearer to the primary between each make and break, and record the result on the muscle, noting each time the position of the secondary coil.

Repeat the experiment with the electrodes on the sciatic nerve.

Do the Two Poles act in the same way ?

METHODS.—Connect wires with the terminals *G*, and introduce a commutator into the circuit (figs. 8 and 9), so that the current may be sent in either direction, and each terminal or electrode made positive or negative as desired.

(*a*) Now expose the heart of a frog (p. 44, II.) and hold an

electrode upon the ventricle, while the other electrode is connected with the moist skin. By changing the commutator, make the electrode upon the heart first the positive pole and then the negative pole, and note any difference in the effect of each upon the muscle of heart when it contracts.

(*b*) Make a muscle-nerve preparation as described on p. 17. Dip the end of the nerve furthest from the muscle momentarily into boiling water to kill it. It will not now respond to the electric current although it will conduct it.

Place the dead bit of nerve over one electrode, and place the other electrode on the nerve near the muscle. Now make and then break the current (1) with the positive pole on the living bit of nerve, and (2) with the negative pole on the living bit of nerve, and record your results on the subjoined table :

	Make.		Flow.		Break.	
	+	-	+	-	+	-
Strong - -						
Medium - -						
Weak - -						

B. On Nerve and Muscle through the Skin.

Arrange the wires to use the current from the terminals *G* and introduce a commutator to change the direction of the current when desired (figs. 8 and 9). Put some saturated salt solution in a basin and fix the end of one wire in the solution. To the end of the other wire attach a flat zinc electrode, placing a bit of chamois leather saturated with the salt solution between the electrode and the skin. Dip the fingers of the left hand into the salt solution and apply the flat electrode over the back of the thenar muscles.

Beginning with a strong current, record the results which follow making and breaking the current. Then by moving the handle on the switch-board from S. to W. reduce the

strength of the current and again record the results which follow making and breaking the current.

Now reverse the direction of the current by means of the commutator, and again study the effects of strong, medium, and weak currents.

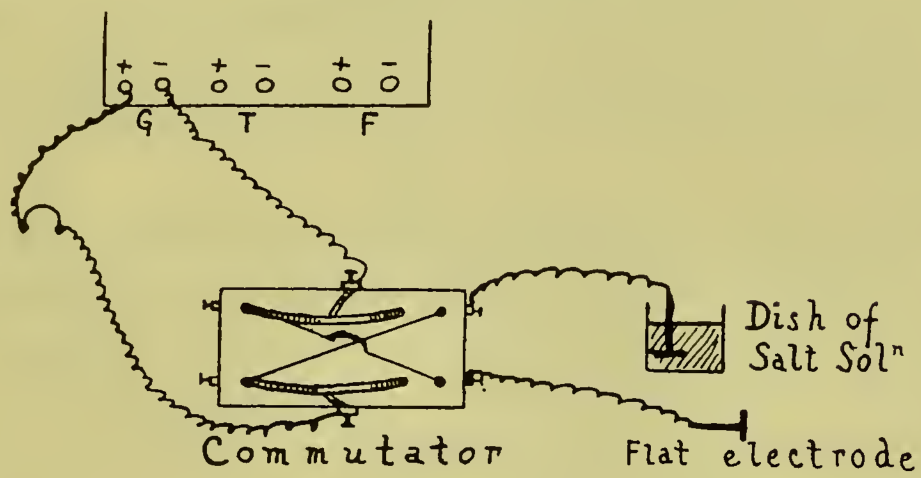

FIG. 8.—Electrical Stimulation of Muscle through Skin.

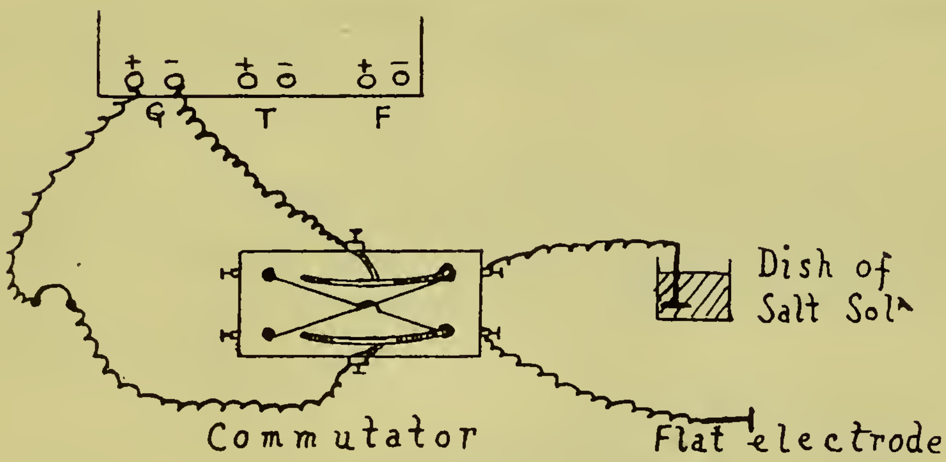

FIG. 9.

Record the results obtained on the following table :

Strength of Current.	Make.		Break.	
	+	-	+	-
Strong - - - -				
Medium - - - -				
Weak - - - -				

and compare them with the results previously obtained on the isolated nerve-muscle of the frog.

V. What happens to a Muscle when Stimulated?

Examine the biceps muscle when the forearm is flexed, and formulate the results of your observations.

A. Extent of Contraction.

With the hand in supination and the arm semiflexed measure the length of the biceps. Now flex the forearm to a small extent and measure the space through which the hand has been moved.

From the elbow articulation measure the length of the forearm and hand to the finger tips, and also to the insertion of the biceps. Make a diagram and from these data and your knowledge of the mechanism of levers, calculate the extent to which the muscle has shortened.

Extent of contraction

$$= \frac{\text{length of lever from fulcrum to power}}{\text{total length of lever}} \times \text{height of lift of hand,}$$

B. Force of Contraction.

Lift a weight of 2 kilograms in the hand, as in the previous experiment, and calculate what weight directly applied to the muscle without the lever this represents.

This is a measure of the force of the particular contraction.

Force of contraction may be expressed by—

$$= \frac{\text{length of lever from fulcrum to weight}}{\text{length of lever from fulcrum to power}} \times \text{weight lifted.}$$

C. Work Done.

From the extent of shortening of the muscle, and from the weight lifted, calculate the work done by the biceps muscle.

Work done = force of contraction × extent of contraction.

D. What is the Course of Contraction of a Muscle?

Method.—Make a frog's gastrocnemius record its change upon a moving surface.

1. Prepare an *Induction Coil* for single induction shocks, putting the *Drum* covered with smoked paper in the primary

circuit, so that the bar on the drum makes and breaks the circuit as the drum revolves (fig. 10). With the hand move the drum so as to make and break the circuit and test the

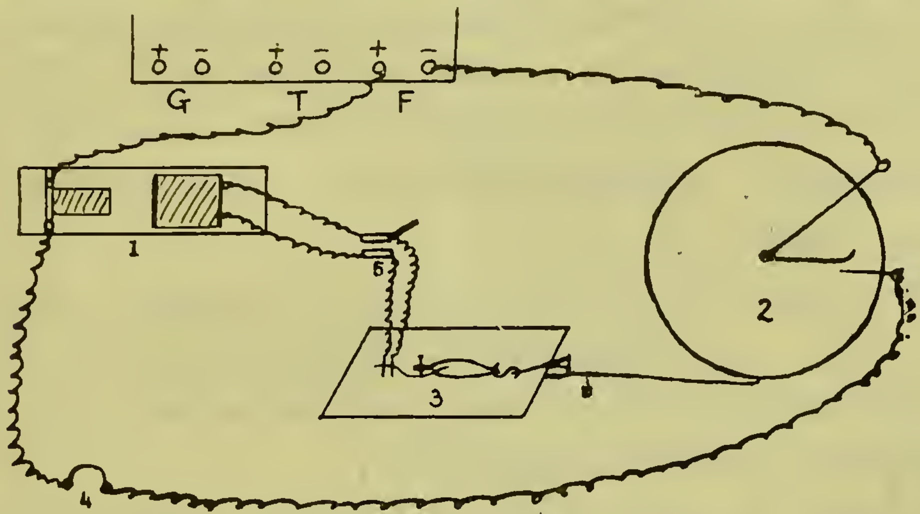

Fig. 10.—Course of Contraction of Muscle.

1. Induction Coil. 2. Drum. 3. Frogboard. 4. Mercury Key. 5. Friction Key.

current passing to the electrodes by applying them to the tip of the tongue. Arrange the driving cord of the drum to give a high rate of speed.

If two students are working together it is convenient to introduce two strikers under the drum in a straight line with one another, so that each revolution of the drum will give two stimulations of the muscle.

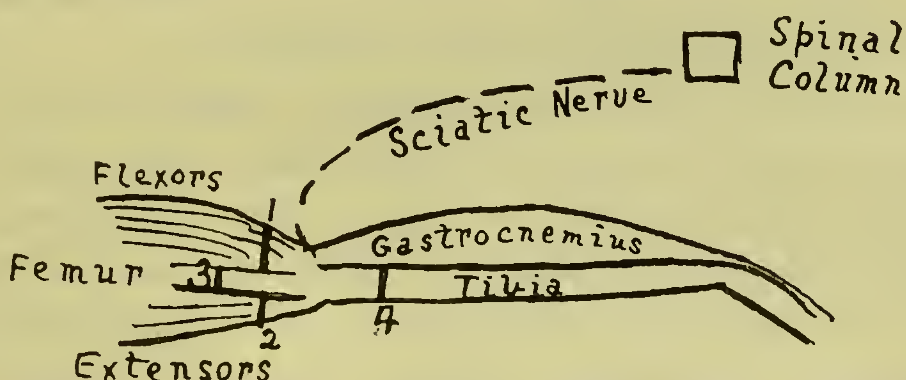

Fig. 11.

2. When everything is ready make a muscle-nerve preparation, isolating the gastrocnemius from its connection with the foot, cutting away all the thigh but the lower end of the femur (fig. 11 (1, 2, and 3)) and cutting through the tibia below the knee (fig. 11 (4)), and thus removing it and the foot. Attach the tendon by a thread and hook or clip to the middle hole

of the short limb of the crank lever. Lay the muscle and nerve upon a piece of blotting paper wet with ·75 % NaCl solution lying on the cork plate. Fix the femoral end of the muscle to the cork plate by a pin passed through the femur, so that the lever is supported in a horizontal position by the thread (fig. 12). Put a small weight on the lever so as just to clear the stand. See that the lever is not resting on the screw-pin below it.

3. Now place the nerve upon the electrodes fixed to the cork by a pin, and making and breaking the current by moving the drum with the hand, move the secondary coil out till breaking alone causes a contraction.

Now bring the point of the lever lightly against the smoked surface of the drum, pointing it in the direction in which the

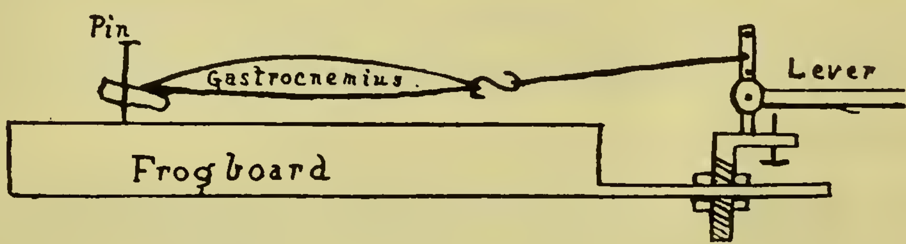

Fig. 12.—Muscle attached to Lever.

drum travels, *and taking care that the movable base-piece is pushed thoroughly home*, so that the lever may be swung off and on to the drum when required. With the key in the secondary circuit closed start the drum, and, when it is revolving steadily, open the key so that the current may reach the electrodes and nerve. When the muscle is stimulated it contracts and pulls up the lever and records the contraction on the drum. *Whenever the record is made, close the key again and stop the drum.*

4. To mark the moment of stimulation, revolve the drum slowly with the hand till the bar just breaks the contact. The muscle will contract, jerk up the lever and mark the moment of stimulation. Note the relationship of this mark, which indicates the moment of stimulation, to the upstroke which marks the contraction.

5. Swing the lever off the paper by using the base-piece.

6. To measure the duration of the different phases of the contraction, fit the electro-magnetic time-marker on the stand and connect it with the time-marker terminals T, which are connected with a general time-marker set to mark $\frac{1}{100}$ of a second. Set the drum going, and, when it is revolving uniformly, bring the tip of the time-marking lever against it by means of the movable base-piece, and let it record its vibrations for a whole revolution. Each tooth on the tracing represents $\frac{1}{100}$ second.

Make two tracings, one for each Student.

7. With a pin or other sharp-pointed instrument write upon the paper the nature of the experiment and the date.

8. Remove the paper from the drum, and fix the trace by passing it through photographic varnish. Hang it up to dry.

9. When dry study the trace and measure the duration of—

1st. The time between the application of the stimulation and the contraction.

2nd. The time taken up by the contraction.

3rd. The time of relaxation.

And record them.

E. Extent of Contraction.

Measure the extent of contraction and the length of each limb of the lever, and calculate the actual shortening of the muscle as in A, p. 16.

Measure the length of the muscle and calculate the percentage shortening.

F. Weight Lifted.

Measure the position of the weight upon the lever, and calculate the actual weight lifted by the muscle as in B, p. 16.

G. Work Done.

Calculate the work done by the muscle.

Preserve the trace and the calculations in your note-book.

VI. Influence of Various Factors upon the Course of Muscular Contraction.

Arrange an experiment in the same way as the last, and take a trace of a muscle twitch with a breaking shock. Mark the point of stimulation.

Each pair of students does one of the following experiments, and then compares their tracings with the others at the same side of the table.

I. Effect of Temperature.

METHOD.—Swing the lever off the drum by the base-piece, and cool down the muscle by putting ice round it, separating the ice from the muscle by a piece of blotting paper saturated with normal saline, and after 2 or 3 minutes swing the lever on to the previous abscissal line, raising or lowering the drum if this is necessary, and take another trace.

Then, proceeding in the same way, warm the muscle by allowing normal saline at 25° C. to run over it for 2 or 3 minutes, and take another tracing.

Mark the point of stimulation, take a time trace and fix.

II. Effect of Continued Exercise.

METHOD.—Having arranged the apparatus for taking a trace of a muscle contraction, start the drum and let the muscle be stimulated, and record its contraction with each revolution or each fifth revolution of the drum. In this way study the effect of continued exercise on muscular contraction.

Mark the point of stimulation, take a time tracing and fix.

III. Effect of the Strength of the Stimulus.

1. *On the Course of Contraction.* METHOD.—Starting with the smallest stimulus which will give a contraction, *i.e.* with the secondary coil as far out as will give a contraction, take a tracing as described above. Then push the secondary coil nearer the primary and take a second record, and then again

nearer and get a third record. Mark the point of stimulation, take a time tracing and fix.

Study the effect of varying the strength of the stimulus on the duration of the phases and the extent of contraction.

If, with the strongest stimulus used, a shoulder should appear on the ascent of the curve, explain how it has been caused.

2. *On the Extent of Contraction.* METHOD.—Disconnect the drum from the primary circuit, and introduce a mercury key by which the current may be made and broken. Bring the lever against the drum unconnected with the driving wheel and, with the drum stationary, record the effect of the minimal effective stimulus and of stronger and stronger stimuli, moving the drum about a quarter of an inch between each record.

A stimulus which is too weak to cause a contraction is called a *subminimal* stimulus.

Mark under each upstroke the position of the secondary coil.

IV. Influence of Load.

1. *On the Course of Contraction.* METHOD.—Take a trace of a muscle twitch when no weight is on the lever, as described on p. 17. Closing the key in the secondary circuit when the trace is made, stop the drum and swing the lever off. Hang a weight of 10 gms. on the lever so that the thread from the muscle and that from the weight are equidistant from the fulcrum. See that the lever is not resting on the screw pin. Lower the drum till the point of the lever marks the same abscissa as before and take another trace. Then move the weight to a measured distance further out on the lever, and take another trace. Repeat with the weight still farther out.

Mark the point of stimulation, take a time trace and fix.

2. *On the Extent of Contraction.* METHOD.—Proceed as in III. 2, but instead of varying the strength of the stimulus go on increasing the weight attached to the lever and mark under

each upstroke the weight used, calculated as directly applied to the muscle.

Make a diagram, showing and comparing the work done with each weight.

(*After taking each trace formulate your* CONCLUSIONS *as to the effect of the particular condition.*)

VII. What is the effect of a Rapid Succession of Stimuli?

METHODS.—1. Arrange two strikers on the axle of the drum, and with them far apart take a trace of the muscle twitches

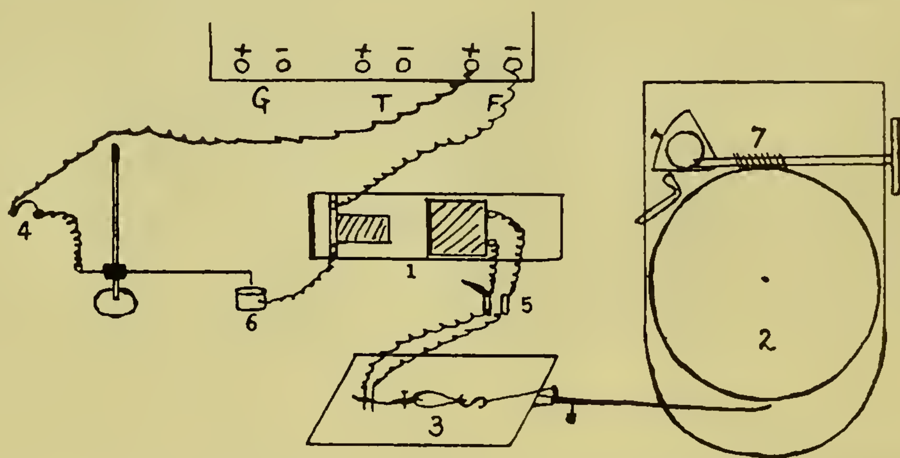

FIG. 13.—Effect of a Rapid Succession of Stimuli.

1. Induction Coil.
2. Drum.
3. Frogboard.
4. Mercury Key.
5. Friction Key.
6. Vibrating Spring with Cup containing Mercury.
7. Gear for producing Slow Rotation of the Drum.

at the top of the drum. Then approximate the strikers so that the second contraction will be produced before the first has ceased, move the drum so that the lever writes at a lower level, and take a trace.

Note the relationship of the second contraction to the first, upon which it is superimposed.

Mark the moments of stimulation, and take a time trace.

2. Now disconnect the drum from the primary circuit and introduce a spring, so that as it vibrates it makes and breaks the current by dipping into a mercury cup (see diagram, fig. 13). Set the drum going *slowly*, and set the spring so that it makes and breaks 5 to 10 times per second. Bring

the point of the lever upon the drum. Open the key in the secondary circuit and take a trace for about 1 or 2 seconds.

Now move the lever to another part of the drum, shorten the spring, and take another trace of the same duration.

3. Repeat with a still shorter spring.

4. Finally connect with the Neef's hammer of the induction coil—a very short rapidly-vibrating spring—and take another tracing. Fix the tracing and study the results of a succession of stimuli and formulate your CONCLUSIONS from these results.

III. THE NERVOUS MECHANISM.

I. Simple Neuron Action.

i. How is the Activity of the Neuron manifested?

METHODS.—1. Make a nerve-muscle preparation, leaving the foot attached as a signal as on p. 11, dissecting out the whole length of the sciatic nerve to the spinal cord, and taking *care to leave attached to the nerve a long piece of the branch to the posterior muscles of the thigh.* Stimulate the sciatic nerve, using an induction coil and Neef's hammer. There is no manifest change in it. There is a change in the muscle to which the nerve goes. (Keep the preparation cool and moist.)

2. Pinch your ulnar nerve behind the internal condyle of the humerus—a *sensation* is produced.

Where is the change manifested ?

ii. Does the Impulse travel in one or in both Directions? (Paradoxical Contraction.)

METHOD.—Isolate the branch of the nerve to the posterior muscles of the thigh and place it upon electrodes. Stimulate, and note whether the gastrocnemius contracts.

What is the explanation of this ?

iii. Effect of Repeating a Subminimal Stimulus.

METHOD.—Fit up the apparatus as in p. 22, 2, using the spring as a key. Pull out the secondary coil till breaking the primary circuit gives a subminimal stimulus. Now set the spring vibrating so as to give a series of subminimal stimuli and note the result. CONCLUSION ?

iv. The Excitation of the Nerve may be measured by the Extent of Contraction of the Muscle to which it goes.

Study the results of the experiments, p. 20, III., on the influence of Strength of Stimulus.

v. Is a Neuron stimulated throughout its whole Extent at once, or does the Change pass along it?

METHOD.—In the secondary circuit of an induction coil place a commutator with the cross wires removed, and connect a pair of wire electrodes with each pair of the terminals, so that by moving the bridge the current may be sent into one or other of the pairs of electrodes. Connect the muscle of the preparation with a crank lever, and place the electrodes upon the nerve—one pair near to and one pair as far as possible from the muscle. Bring the lever against a very fast drum, and take a separate tracing of the muscle twitch with the nerve stimulated by each pair of electrodes. Finally, put a time tracing of $\frac{1}{100}$ of a second on the drum and measure the length of nerve between the two electrodes.

Formulate your CONCLUSIONS.

vi. Is a Nerve more easily stimulated from its Termination or from its Middle?

METHOD.—Destroy the brain of a frog and expose one sciatic nerve, without injuring it, by passing a bristle under it to raise it to the surface.

Using the "reflex" contraction of the other foot as an index of the extent of stimulation, II., B, p. 25, stimulate with forceps, first the termination of the nerve in the toes, and then

the exposed nerve, and note any difference in the result. CONCLUSION ?

II. What is Reflex Action ?

1. Phenomena of Reflex Action.

METHODS.—Prepare an induction coil with Neef's hammer. Have a basin of water beside you. Hang the frog used in the last experiment to the frog-plate, fixing it by a pin through the jaw.

A. *Are reflex movements co-ordinated?* Apply a very small scrap of blotting paper dipped in acetic acid to the flank of the animal. Study the movements.

Having washed off the acetic acid—

B. *Relationship of reflex to stimulus?* Pinch the foot with forceps and study the result as regards—

1. Movements which result.
2. Relation of these movements to the strength of the stimulus. Vary the strength of the pinch, or vary the strength of the induced current.
3. Duration of the movements. How long maintained with different strengths of stimulus ?
4. Spread of the movements. Study the order of this.

C. *What is the effect of a series of subminimal stimuli in liberating a reflex action?*

Fit up the apparatus as on p. 24, iii., and stimulate the foot with—

1. Single induced shocks,
2. A series of shocks of the same strength,

and compare with the result of iii., p. 24. CONCLUSION ?

2.—A. Is time taken up in Reflex Action ?

METHOD.—Using the same frog, dip the foot first into the weak acid supplied, and, after washing in the vessel of water, into the stronger acid. Note the difference in time of onset of the reflex action.

B. How may the time be measured?

Method.—Using the same frog, lay it on the cork board of a myograph, fixing the lower end of the femur and the tibia with pins.

Free the tendo-Achillis and attach it to the lever. Bring the electrodes from the secondary coil of an induction apparatus upon the toes of the same foot and arrange the primary circuit for tetanising shocks with Neef's hammer. Attach a piece of copper wire to the striker on the drum so as to make a prolonged contact with the knife edge. Adjust the coil so that each stimulation gives a reflex response to the gastrocnemius.

Now start the drum, and when it is rotating smoothly stimulate by opening the key in the secondary circuit, and get a record of the moment of contraction. Then mark the moment of stimulation.

Now remove the myograph and with the drum going uniformly put a time marking of $\frac{1}{100}$ of a second under the tracing. Remove the tracing and measure the latent period, and compare with the latent period in a simple muscle twitch (p. 19).

3. Is Reflex Action dependant on the Spinal Cord?

Now destroy the spinal cord and observe the effect on reflex action. Conclusion ?

4. The Knee-jerk.

One student sits with the right leg crossed on the left, closes his eyes and firmly clasps his two hands together. With the edge of the ear-piece of a simple stethoscope or with the side of the hand another student strikes the ligamentum patellæ of the right leg, and observes the contraction of the quadriceps extensor femoris and the movement of the leg.

III. What time is taken in Nerve Actions when the Brain is involved? (Visual Stimuli.)

Method. Connect in one circuit, through the terminals marked *F*, two mercury keys, *A* and *B*, separated by a considerable length of wire, connected with a time-marker *C*, so that when both keys are closed the current passes and the lever on the time-marker is depressed. Bring the lever of the time-marker *C* lightly against the smoked surface of a rapidly revolving drum. One student stands beside the drum and lever watching this lever, holding the handle of a closed mercury key, *A*, which he must open the moment he sees the lever depressed. The other now closes the other mercury key, *B*, in such a way that the subject can neither see nor hear the closing. The lever is thus momentarily depressed. It is released again when the first student opens *A*. A time tracing in $\frac{1}{100}$ sec. is put below the record thus obtained. The tracing is fixed, and the interval between the application of the stimulus and the resulting action is measured and recorded.

IV. What is the result of continuance of Reflex Action? Fatigue of the Neuro-muscular Mechanism.

Method.—Fit the hand and arm in a Mosso's ergograph to the hook of which a weight of 3 kilograms has been attached. Bring the writing point against a very slowly moving drum. Set a metronome beating about 60 times per minute, and as each beat is heard raise and lower the weight with the finger to the fullest extent as long as it is possible to move the weight, then study the record of the onset of fatigue upon the drum. Compare your record with those of others.

IV. RECEPTOR MECHANISMS—THE SENSES.

How do different External Conditions act upon the body?

I. CONTACT WITH GROSS MATTER. TOUCH.

With the eyes shut touch any object, *e.g.* the table, and try to formulate all that you can learn about it through the sense of touch.

Hardness or softness—how determined ?
Roughness or smoothness—how determined ?
Temperature—how determined ?

I. Is Contact felt equally all over the Surface?

Method.—Fit two or three brush bristles of different strengths into split wooden matches. One student now lays his hand on the table, palm downwards, and closes his eyes. The other touches various points close together over a small part of the back of the hand, and the student experimented upon says whether he feels the contact or not. The points on which contacts are clearly felt are mapped out (Pressure Spots). By more firm pressure Pain Spots may also be discovered and mapped.

II. What Differences of Pressure can be distinguished?

Method.—One student lays his hand on the table palm upwards. He keeps his eyes closed while another student applies to the palmar aspect of the proximal phalanx of the middle finger the different weights supplied. The weights must be applied to the same place in the same way each time, and at as nearly as possible equal intervals of time. They must be left on for the same time. As each weight is applied the subject of the experiment says, " the same," unless he is *sure* that there is a difference, in which case he says

"heavier" or "lighter." Recording the result of each observation, the experimenter then determines and records the smallest percentage difference of weight which can be appreciated.

III. Can the Point of Contact be localised equally well at all Parts of the Surface?

METHOD.—The acuteness of this may be determined by finding how near to one another two contacts may be made and still give rise to a sensation of two and not simply of one contact.

One student closes his eyes and lays his hand palm downwards on the table. The experimenter then takes a pair of compasses, and, holding them loosely in the hand with the points somewhat separated from one another, he lightly brings either one point or the two points simultaneously down upon the back of the subject's hand. The subject must say "one" unless he is certain that he feels two points of contact. Working in this way, and recording the result of each observation as to the distance of the points and the resulting sensation, the experimenter determines and records how far the points must be apart on the back of the hand to give rise with certainty to a double sensation.

The observation is next to be repeated on the palmar aspect of the terminal phalanx of the forefinger.

IV. Can Contacts be distinguished however rapidly they follow one another?

METHOD.—Place the finger upon the toothed wheel first when it is rotating slowly and then when it is rotating rapidly, and note in each case if a *series* of sensations or a continuous sensation is experienced. The contacts are practically instantaneous. What CONCLUSIONS do you draw as to the duration of the sensations?

II. HOW IS THE TEMPERATURE OF EXTERNAL OBJECTS DETERMINED? TEMPERATURE SENSE.

I. Is the actual Temperature appreciated?

Methods.—Take three basins.

1. Fill one with water so hot that the hand can be just comfortably held in it.

2. Fill another with cold water.

3. Fill the third with water at a temperature intermediate between 1 and 2.

Place one hand in 1 and the other in 2, and after keeping them there for a few minutes place both in 3 and record the sensation in each. What Conclusion do you draw as to the nature of the temperature sense?

II. What factors determine the sensation?

Method.—Bring a piece of metal and a piece of flannel, which have been kept at the room temperature, upon the skin and notice the difference in the sensation produced. What is the explanation?

III. Is the power of determining Temperature equally distributed over the skin?

Method.—With a cold metal point gently touch the back of the hand between the fourth and fifth metacarpal bones and notice if the sensation of cold is produced by contact everywhere or only at certain spots.

Repeat the experiment with the metal at a higher temperature than the body.

Repeat the experiment on the back of the forearm. Conclusions?

IV. What is the smallest difference of Temperature which can be appreciated?

Method.—Take two large test-tubes and place a thermometer in each. Half fill them with water at between 35° and

40° C., and then making one slightly colder than the other, find the smallest difference of temperature which can be appreciated (*a*) with the tubes on the side of the face, (*b*) with the tubes on the back of the forearm.

III. TASTE.

Is the sensibility to taste the same all over the Tongue?

METHOD.—Solutions of (1) Sugar,
(2) Quinine,
(3) Hydrochloric Acid,
(4) Common Salt,

are given you. One student rinses out the mouth with water and another applies, with a camel's hair brush, one or other of the solutions to some part of the tongue and notes the sensation which is said to be produced. The mouth is again rinsed and the process repeated, and thus the various parts of the tongue are investigated for their sensibility to the different substances. The results should be recorded as a diagram.

Cocaine may be painted upon the tongue and the tactile and gustatory response studied.

IV. VISION.

A. Structure.

I. Ox Eye out of Formalin.

Examine the eye. Identify the cornea and sclerotic and notice the entrance of the optic nerve to the inner side of the posterior axis. Note the shape of the pupil. Now divide the eye into an anterior and a posterior half by cutting through the equator of the sclerotic with a sharp razor.

Note the gelatinous vitreous humor in the posterior chamber. Note the black coloured choroid coat inside the

sclerotic. In the anterior segment note that the capsule of the vitreous (hyaloid membrane) is firmly attached to the front of the choroid and that it holds the lens in a capsule behind the pupil. Strip the hyaloid membrane and the lens in its capsule from the choroid and observe how firmly attached it is to a series of ridge-like thickenings of the choroid just behind the junction of the cornea and sclerotic—the ciliary processes. Examine these processes. Note that the iris is continued forward from them to the edge of the pupil.

Shell the crystalline lens out of its capsule. Study its shape and note its elastic character.

Observe the aqueous humor in front of the lens and behind the cornea, filling the anterior chamber.

Now make a section through the cornea and sclerotic at right angles to the last cut and study the corneo-sclerotic junction and draw it.

In the posterior segment of the eye note the entrance of the optic nerve, and observe the thin membrane-like retina spread over the choroid. Note the iridescence in front of the choroid in the eye of the ox. Observe the blood vessels entering in the optic nerve and spreading over the front of the retina. (In the eye of the ox there is no special development of a macula lutea in the posterior optic axis.) Make drawings of the various structures seen.

Revise the histology of the different structures.

II. Examination of the Eye in Life.

Ophthalmoscope.

Make a model eye by unscrewing the lower lens of a microscope eyepiece and placing inside it a piece of paper with some mark upon it. Look through the upper lens, and observe that the chamber is dark and the paper is not distinctly seen.

Direct Method.—In the optical room fix the artificial eye in the holder. Using the mirror with a hole in the centre, reflect the appropriate light into the eye, looking through the

hole. Begin at a distance of two feet from the eye, and gradually approach it, keeping the light reflected into it. Gradually the mark on the paper becomes distinctly visible. Is it erect or inverted ?

Indirect Method.—With the mirror about three feet from the eye reflect the light into it. Now insert a biconvex lens at about 4 or 5 inches in front of the eye, and try to see the image of the mark on the paper. Is it erect or inverted ?

The human eye may be examined in the same way.

B. Vision with One Eye.

I. The Focussing Mechanism.

I. The Formation of Images in the Retina.

METHODS.—A. Study the formation of images on an obscure glass screen behind a lens.

1. Where are objects held above focussed on the screen and where are objects on the right focussed ? Is the image erect or inverted ?

2. Can a near object and a far object be focussed at the same time ?

3. What is the relationship of the size of the image to the distance of the object ?

Revise your knowledge of the optical properties of a convex lens.

B. Examine the image of a candle formed on an obscure glass plate placed over a hole cut in the back of a fresh ox's eye.

II. At what Surfaces of the Eye are the Rays of Light refracted ?

Note the formation of a reflected image from each of the two refracting surfaces of a biconvex lens. Study how the size of the image varies with the curvature of the lens, the

position of the image from each surface of the lens and the direction in which it moves when the object is moved.

METHOD.—*Sanson's Images.* In a dark room hold a candle to the outer side of the eye of a fellow student, and notice that three reflected images are to be seen—one large, clear, distinct, erect image from the anterior surface of the cornea, one small distinct inverted image from the posterior surface of the lens and one much less distinct erect image, larger than the first and apparently lying almost behind it and seen best from the side away from the light, from the anterior surface of the lens. From the size of these images draw conclusions as to the relative curvatures of the different surfaces.

Why is no image formed from the posterior surface of the cornea?

From the results of these observations, make a diagram of the Physiological Lens of the Eye.

III. Can Near and Far Objects be seen at the same time?

METHODS.—A. Close one eye and fix the other on the far corner of the room, and then hold up a pencil at about a foot from the eye and see if *at the same time* both objects can be distinctly seen. When the eye is directed to the pencil, note any change in the pupil.

B. *Scheiner's Experiment.* Make two holes in a horizontal line in a sheet of paper so near that they both fall within the diameter of the pupil. Now stand at about two or three yards from a wall on which a small vertical line is drawn and look at it through the holes. While keeping the eye fixed on the line bring a needle vertically in front of the holes at about eight inches from the eye, and note the appearance of the needle when the distant line is looked at, and the line when the needle is looked at.

Make a diagram of the experiment and formulate the conclusions to be drawn.

IV. Is the Power of Focussing Limited or Unlimited?

METHOD.—Bring a pencil point held vertically nearer and nearer to the eye; a point is reached within which it cannot be distinctly seen—the near point. Measure the distance of this from the eye and record it.

V. What change takes place in the Eye in Near Vision?

METHOD.—Repeat the experiment on the refracting surfaces of the eye (p. 34), when the observed eye is looking at a distant and at a near object.

Examine again, using a Phacoscope as demonstrated.

Make a diagram of the results arrived at.

II. Action of the Retina and Brain.

I. Are Visual Sensations produced by Light only?

Press upon the eye-ball far back, and note the effect of such mechanical pressure on the retina.

II. Is the whole Retina stimulated by Light?

METHODS.—1. *Mariotte's Experiment.* Make two marks about 4 inches apart upon a piece of plain paper.

With the left eye closed, *fix* the right eye on the left-hand mark with the head about 18 inches from the paper.

Are both marks visible? Does any change take place as the paper is gradually brought towards the face?

Make a diagram of the results of the experiment.

2. Make a mark on the left side of a piece of plain paper. Holding the head firmly fixed at about a foot from the paper, with the right eye *fixed* upon the mark, the left eye being closed, move the point of a pencil held nearly horizontally slowly towards the right side of the paper. Note any change in the appearance of the point of the pencil you may observe.

Make a diagram of the experiment. CONCLUSIONS?

Map out the blind spot.

III. What Layer of the Retina is acted upon by Light?

METHOD.—*Purkinje's Images.* In a dark room stand side on against a uniformly coloured wall, with the eyes turned towards the wall. By means of a lens another student directs a powerful ray of light through the exposed sclerotic coat of the eye, and, on moving the light up and down, and from side to side, any appearance on the wall is noted. The lines seen are the shadows of the retinal blood vessels. Revise your knowledge of the distribution of the blood vessels of the retina. CONCLUSION? Is it the front layer of retina or a back layer which is acted upon by light?

IV. Is the power of Localising the source of Light equally developed all over the Retina?

METHOD.—Prepare an experiment as on p. 35, II. 2, but instead of a pencil take a pair of compasses. Bring the points close together, and place the points on the central mark, and note whether both can be seen. Now draw them along the paper away from the central mark, keeping the eye fixed on the central mark, and note whether the two points can be distinguished. Separate them till they are again seen as two and draw them still further out, and note what happens. Record the result on a diagram and formulate your conclusions.

V. What range of objects can be seen at one time?

The Field of Vision.

METHOD.—A. *Black and White.* Describe a semicircle on a black-board with the free ends of the line finishing at the side. Mark the centre of the circle and the middle point in the circumference with an X. This forms a rough "perimeter."

With one eye closed the observer places his other eye at the centre and directs it steadily towards the middle point

in the circumference. A fellow student slowly draws a piece of chalk along the circumference from below. He notes when it becomes visible and marks this point.

Now, starting from above, the experimenter again draws the chalk along the circumference until it becomes visible, and marks the point where it comes into view. The angle thus formed with the centre of the circle and these points subtends the vertical field of vision. Measure this angle and record it.

Now turn the blackboard into the horizontal plane, or use the top of the table, and map out the horizontal field of vision.

B. *Colours.* Using coloured chalks, map out the field of vision for the different colours red, green, blue and yellow, noting the points at which *the colour* becomes clearly distinguishable. Measure and record the angles. Draw a section of the eye and mark upon it the parts of the retina which react to black and white, red, green, yellow and blue.

Repeat these observations using a Perimeter.

VI. How are Colours perceived?

Revise your knowledge of the physical nature of colour. Study the spectrum produced by a prism.

1. How are the various Colours in Nature produced?

1. Methods.—Fix a disc of pure spectral colour, *e.g.* red, on the rotating disc in a good light, and after rotating the disc and observing it, by means of the slit, introduce (*a*) a segment of white, rotate and observe; (*b*) a segment of black, rotate and observe; (*c*) a large segment of bluey green, rotate and observe. Record your results and draw conclusions as to the effect upon the colour sensation of mixing a spectral colour with (*a*) white (diluting it), (*b*) black (decreasing the illumination), and (*c*) another part of the spectrum.

2. Are Colour Sensations produced only by Ethereal Vibrations of different Lengths?

Methods.—(1) Insert the tip of the little finger into the external angle of the eye, getting it as far back as possible and turning the eye inwards. Now press, and notice if any colour sensation is produced.

(2) Make a white card-board disc with one half blackened, and draw lines as shown in the class disc. Put a needle through the centre and rotate it as rapidly as possible in a good light, and notice the effect produced. Conclusion?

3. What is the effect of prolonged Stimulation of the Eye with any one part of the Spectrum?

Method.—Put a disc of red paper on a white ground in a strong light. Look steadily at it for half a minute, then remove it and continue to look at the white surface, and note what happens. Repeat this with discs of different colours.

The colour which appears is said to be complemental to the first.

4. What is the effect of combining these Complemental Colours?

Method.—On a black surface place two discs of complemental colours. Between them place vertically a sheet of glass. Now tilt the glass towards one of the discs, and on looking through it the image of the disc is thrown on the other disc. Note the colour change produced.

5. Is the power of appreciating Colour equal all over the Retina?

Study the result recorded on p. 37, B, and draw your conclusions.

6. Can all Individuals distinguish Colours equally well?

Methods.—Take a set of Holmgren's wools. Give a student a red wool and let him pick out all that are of the same sort of colour. Find if any member of the class is colour blind.

VII. Effects of Strong or Prolonged Stimulation?

Methods.—(*a*) After keeping the eyes closed for two minutes look steadily at a white mark on a black surface for a few seconds and then close the eyes.

Describe the image that appears and also any change in its intensity as time passes—Positive After Image.

(*b*) Look steadily at the same mark for three minutes and then close the eyes.

Describe the image as above—Negative After Image.

(*c*) *Colour.* Using the colour square supplied study the after images as in (*a*) and (*b*).

VIII. How far does our Visual Perception give us a true knowledge of our surroundings?

Modified Visual Perceptions.

Methods.—1. Two squares of equal size are fixed upon paper: one is white, placed upon a black ground, and one black, placed upon a white ground. Which appears larger, and why?

2. Place three equidistant dots in a straight line on a piece of paper and subdivide one division by a series of dots. Which part appears longer, and why?

3. (*a*) A red wafer is placed on a white ground and another on a green ground. Which appears deeper in colour?

(*b*) A red paper is placed on the table with a grey one a foot away on one side and a green a similar distance away on the other.

Does the red appear more intense after looking at the grey or at the green sheet?

4. Rule a square with parallel diagonal lines, and place short vertical and horizontal lines upon the alternate diagonals. Do the latter now appear parallel? If not, why not?

From these experiments draw your Conclusions as to the necessary accuracy of the knowledge gained by vision.

C. Vision with Two Eyes.

I. What are the Advantages?

1. Extent of Field of Vision.

With the perimeter investigate the field of vision in the horizontal plane first for one eye and then for the two eyes, taking care not to move the head. Make a diagram of the result, and compare the optical angle in vision with one and with two eyes.

2. Estimation of Contour.

(*a*) Lay a prism edge on to you on the table, look at it first with one then with two eyes, and consider how the idea of relief is arrived at.

(*b*) With the stereoscope study how the projection of slightly different pictures on the two retinae gives the idea of relief.

3. Estimation of Distance.

Set up a stick vertically at one end of the laboratory, and with one eye closed walk up to it quickly and, without hesitating, try to touch it with the outstretched finger. Repeat this experiment with both eyes open and note any difference of result. What conclusion do you draw from this?

II. Why is there normally Single Vision with Two Eyes?

I. Is Single Vision possible if the Eyes do not move together?

Methods.—1. With the tip of the finger fix one eye in its socket and move the head about, looking at external objects, and notice whether they remain single.

2. Looking straight forward, press with a finger upon one eye to alter its direction, and note the effect upon vision.

Study the anatomy of the eye in the socket and the action

of various muscles which move it. Note that they act round three axes of rotation. Now get an orange and take the pip to represent the pupil. Thrust a knitting needle through each of the three axes of rotation and study the influence of each of the three pairs of muscles upon the direction of the pip or pupil.

II. Can Double Vision be produced when the Eyes move freely together?

METHOD.—Set up a stick vertically about 3 feet from the eyes, and another at about 10 feet. Look at the near one and see what happens to the image of the far one. Close one eye and observe what happens. Now look at the far one and notice the image of the near, and again close one eye. Make a diagram of the experiment, and explain the result.

V. *HEARING.*

Revise your knowledge of the physics of sound vibrations.

I. What Qualities of Sounds are perceived?

1. Loudness.

2. Pitch. Is the perception of pitch limited? Using tuning forks for the lower limit and the steel cylinders supplied for the upper limit, determine the range of perception of musical sounds.

3. Quality. (*a*) Sound the tuning fork Ut_4 strongly, and note the character of the resulting sensation.

(*b*) Repeat the experiment, and immediately after sounding the fundamental tone, sound the three partials *me, soh* and *doh above*, and note the character of the resulting sensation.

(*c*) Repeat the experiment as in 2, sounding this time the three partials *soh, me* and *doh below*, and note the character of the resulting sensations.

Formulate your conclusions as to the influence of upper and of lower partials upon the quality of musical tones.

II. Do Sound Vibrations influence the Internal Ear only through the External?

Methods.—Sound a tuning fork lightly, and hold it to the ear until the sound has quite died away. Now place the end of the fork against the closed teeth. Describe the resulting sensation. What Conclusion do you draw ?

III. Is the Power of localising the Source of Sound well developed?

Test the power of localisation by making a faint clicking noise—as by closing sharply a pair of forceps—in the neighbourhood of the head of the subject whose eyes are closed. The latter must make a definite statement as to where the sound comes from.

VI. HAVE WE THE POWER OF DETERMINING THE POSITION AND MOVEMENTS OF THE VARIOUS PARTS OF OUR BODIES?

Methods.—With the eyes closed, (*a*) put the various parts of the arm, hand and fingers in any position, and try if the position of each part can be determined; (*b*) get some one to put the same parts in any position, and again try if the positions can be accurately described.

(*c*) Take a weight in the hand and study how an estimate of the weight held is arrived at. Has the condition of the muscles, tendons, and joints anything to do with it, and if so, what ? This may be called the Muscle-joint Sense.

To test this sense find the smallest difference of weight which can be detected, as in Appreciation of Pressure, p. 28, II., but keeping the hand free of the table and using the muscles of the arm.

By passing the hand over some object with the eyes shut, study how this sense, in conjunction with touch, gives information as to the distance, shape, and size of external objects.

VII. HAVE WE THE POWER OF DETERMINING THE MOVEMENTS OF THE BODY IN SPACE?

Consider the absence of sensation of movement in smooth running trains, and the sensation of movement on starting and stopping.

1. Spin rapidly round several times, stop and observe the sensation produced.

2. Hold a short stick or poker vertically with its point on the ground. Place the forehead on the top and rapidly walk three times round it. Then raising yourself straight, try to walk to the door. Notice the effect produced and try to explain it.

Revise your knowledge of the anatomy of the semicircular canals of the internal ear on the specimens supplied, and consider how they may act in the above experiments.

V. CIRCULATION.

A. Heart.

I. Structure.

(*Drawings must be made of the various structures.*)

1. Use the sheep's heart supplied. Open the right auricle by a horizontal cut. Open the right ventricle by an inverted V incision as demonstrated.

Examine the tricuspid valve and papillary muscles.

Slit up the pulmonary artery and examine the semilunar valves.

Open the left auricle and ventricle by a vertical antero-posterior incision through the left auriculo-ventricular orifice and middle of the aorta, and examine the mitral valve and papillary muscles, the relations of the anterior cusp of the mitral to the posterior aortic wall and the aortic semilunar valves and mouths of the coronary arteries.

On the septum between the ventricles note that a special

band of muscular fibres passes from the auricles to the ventricles.

2. On the models of the thoracic organs, study the attachments and relations of the heart to the anterior and posterior chest wall, to the central tendon of the diaphragm and to the lungs.

3. In a boiled sheep's heart, twist off the auricles, aorta and pulmonary artery, and examine the auriculo-ventricular and pulmonary fibrous rings.

Clear off the visceral pericardium of the ventricles and study the course of the muscle fibres.

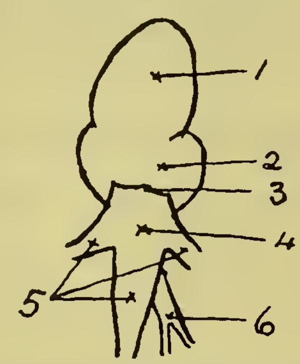

Fig. 14.—Heart from behind.

1. Ventricle.
2. Auricle.
3. Crescent.
4. Sinus.
5. Great Veins.
6. Aorta.

4. In the longitudinal section of the heart given in the Histology Class, study the various parts under a low power.

5. Dissect the heart of a dead frog. Identify the sinus, auricles, ventricle and bulbus arteriosus (fig. 14). Thrust a small test-tube down the gullet to stretch it, and dissect out the vagus nerve and follow its cardiac branch down to the heart.

II. Mode of Action of the Heart.

The Cardiac Cycle.

1. *Study the exposed heart in the frog.* Pith a frog and pin it out on its back on a cork plate. Open the abdomen by an incision a little to one side of the middle line to avoid the anterior abdominal vein, and carry the incision up to the xyphisternum. Then snip through the shoulder girdle in the

anterior median line, taking care that the point of the scissors does not injure the heart. Separate the two sides of the girdle, pinning each back, and then expose the heart in the pericardium. Snip through the pericardium and study the auricles, ventricles and bulbus as seen from the front.

Study the changes in shape which each part undergoes—the relative duration of each change in each part and the sequence of events in the different parts—and record your observations.

Now take the tip of the ventricle in the forceps and lift it up and observe a fold of pericardium, the fraenum, which is attached to it behind. Carefully snip this through, and then turn the ventricle freely forward and study the changes which occur in the sinus venosus, and the relation of these changes to the changes in the other parts of the heart.

2. *Is the heart's action automatic?* Excise the heart with the sinus attached, and place it in a watch glass and study its movements, counting the number of beats per minute.

3. *Influence of Temperature.* Now place the watch glass upon ice and observe the effect. When a marked change in the rhythm has taken place and been recorded, remove the watch glass from the ice and place it upon the palm of the hand and record any change in the rate.

Method of Recording the Cardiac Cycle and of Studying the Nerve Control of the Heart.

1. Connect up the apparatus for giving a series of induced shocks.

2. Set a recording drum on the slow gear.

3. Kill a frog and remove the brain *in front of* the tympanic rings by cutting the head across at that level. Then cut the spinal column and cord across above the shoulders, thus leaving the medulla oblongata isolated and intact with the vagi passing from it to the heart. Thrust a pair of pin electrodes into the medulla, fixing them on the cork by a pin.

A. To Record the Cardiac Cycle.

Place the cork plate with the frog under the heart lever and attach the lever to the apex by means of a small clip, seeing that the thread is vertical (fig. 15). Adjust the lever

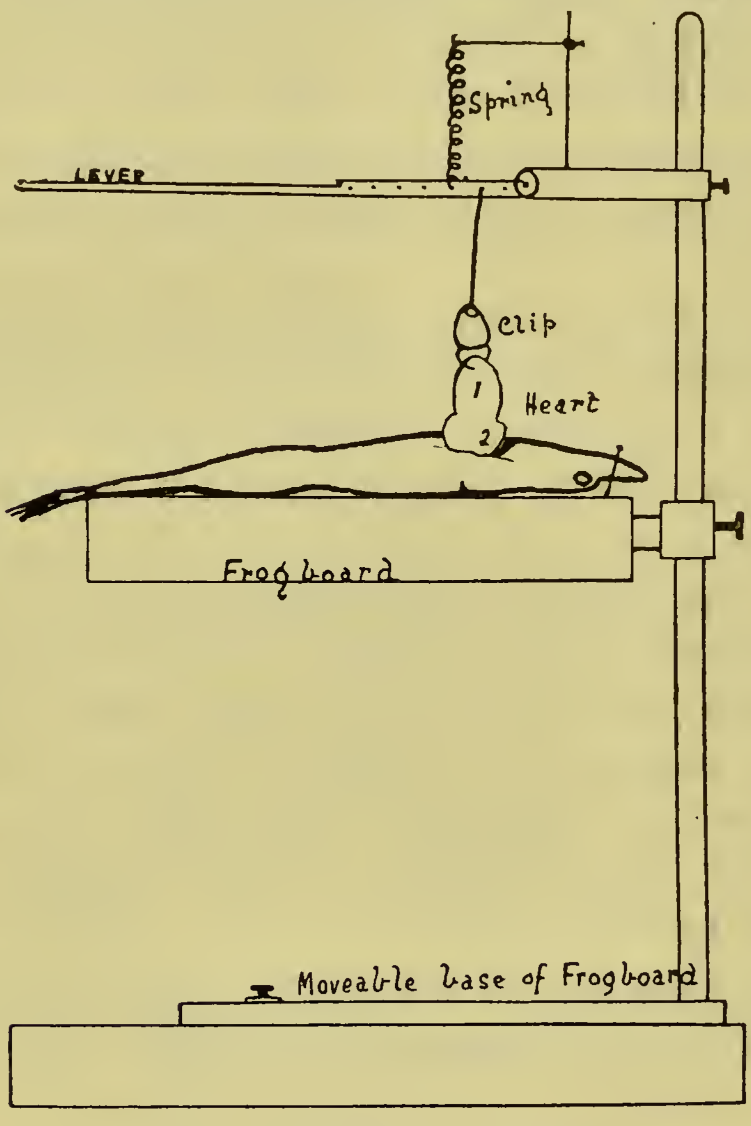

Fig. 15.—Arrangement of Frogboard.

so that each heart beat causes the largest range of movement. Then bring the point of the lever lightly against the drum ; start the drum at a very slow rate, and take a record of several cardiac cycles. Remove the lever and put a time record in tenths of a second under the trace. Fix the tracing.

Now determine

(1) the rate of recurrence of the cardiac cycle, *i.e.* the rate of the heart ;

(2) the duration of the ventricular systole ;

(3) the duration of the auricular systole, if this is marked upon the trace.

B. To Study the Nerve Control of the Heart.

1. *Intra-Cardiac Mechanism.* Stimulate the crescent, which may be seen as a white crescentic mark between the sinus and auricle on their posterior aspect (fig. 14). The current must not be very strong. If no change in the rate of the heart occurs, increase the strength of the current.

Take a tracing. What Conclusion do you draw ?

2. *Extra-Cardiac Mechanism.* Using the pin electrodes in the medulla, stimulate as in 1 and record the result. If no change is produced increase the strength of the current or readjust the electrodes. What Conclusion do you draw ?

3. *Effect of Drugs.* Leaving the electrodes in position as in 2, paint the heart with 0·1 per cent. solution of atropine sulphate. Allow two minutes to elapse and then stimulate. Note any difference from the reaction in 2. Take a tracing and formulate your conclusion.

4. *What is the Influence of the Sinus? Stannius Experiment.* By means of a needle pass a piece of thread under the two aortae, and, turning the ventricle forward, tie a loose loop between the auricles and the sinus (figs. 16 and 18). When the heart has recorded a few contractions, tighten the loop so as to separate the auricles from the sinus. Note and record the result. If the ventricle stops contracting, stimulate it by touching with a needle, marking the moment of stimulation, and record the course of contraction and measure the latent period. What Conclusions do you draw ?

Tie another loose loop round the whole heart after the last ligature has been tied, and tighten it so that it exactly separates the auricles from the ventricle. Record the result.

C. The External Manifestations of the Cardiac Cycle in Man.

1. *The Cardiac Impulse—Cardiograph.* Find the position of the cardiac impulse on the front of the chest of a fellow-student and investigate its characters. Mark its position with

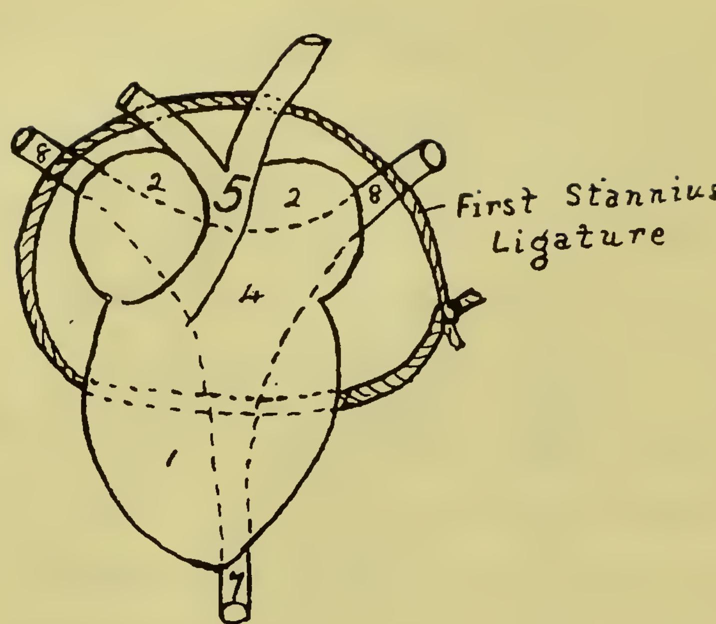

FIG. 16.

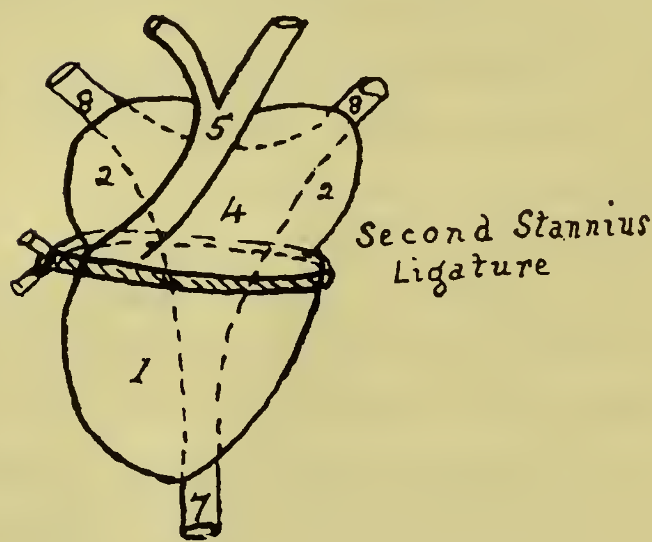

FIG. 17.

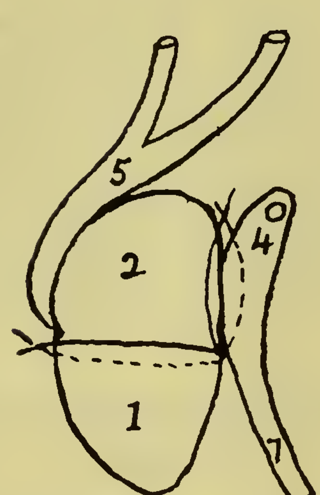

FIG. 18 (side view).

1. Ventricle.
2. Auricle.
4. Sinus.
5. Aorta.
7. Inferior Vena Cava.
8. Superior Vena Cava.

an aniline pencil and then apply the cardiograph with the button upon the impulse and take a tracing on a slow moving drum. This is best done with the subject leaning forward and to the left. Make an enlarged drawing of a part of the trace and try to explain the various elevations and depressions.

2. *Arterial Pulse.* Place a finger of the left hand on the radial artery at the right wrist while feeling the cardiac impulse with the right hand, and note what is felt in the artery. Determine whether the change is simultaneous with the cardiac impulse.

3. *Sounds of the Heart.* With the stethoscope provided listen over the front of the left side of the chest. Put a finger on the cardiac impulse and try to time the sounds heard in relationship to this.

4. *Cardio-pneumatic Movements.* Do the movements of the heart cause movements of the air in the air passages ?

Fill the mouth, nose and pharynx with tobacco or other smoke. Hold the nostrils. Insert a glass tube drawn to a somewhat fine point into the mouth. Stop breathing and keep the glottis open. Note any movement of the smoke in the tube, and time it with the cardiac impulse. CONCLUSIONS ?

B. Circulation in the Blood Vessels.

I. Blood Pressure.

1. *General Distribution.* Examine the schema of the blood vessels made of elastic tubes given you, and identify the parts representing arteries, capillaries and veins. Attach the arterial end to the water tap, and fix vertically in stands the two glass tubes connected with the arteries and veins respectively. Cautiously turn on the water and measure the pressure in the arteries and in the veins, and calculate it in mm. of mercury. Note the effect of (*a*) varying the force of inflow by turning off and on the tap, (*b*) varying the resistance to outflow by constricting the arteriole tubes.

2. *The Arterial Pulse.*

(1) With the finger compress and relax the arterial tube near the tap at regular rhythmic intervals of about a second, so as to imitate the interrupted inflow of blood from the heart. Note the effect of this upon the arterial and venous pressures, and study the further effect of constricting the arterioles.

(2) Place a finger on the arterial tube and note the expansion, the *pulse,* with each inflow. Study the same thing in the venous tubes. Explain any difference which may be observed.

(3) Place the finger on the radial artery of a companion and study the pulse as to (*a*) rate, (*b*) rhythm, (*c*) force, (*d*) size, (*e*) form of wave.

(4) Does the wave develop simultaneously throughout the arterial system or does it pass out to the periphery ? Place one finger over the carotid and another over the radial artery and time the appearance of the wave under each.

(5) Using Dudgeon's or Marey's sphygmograph, under the direction of the demonstrator, take a tracing of the radial pulse. Copy it carefully, and try to explain the various elevations and depressions with reference to the events in the cardiac cycle.

3. *Blood Pressure in Man.* Make an observation of the arterial blood pressure of a companion by the—

Riva Rocci Instrument.

(*a*) Examine the manometer and see that the cap is removed and that the mercury is at zero.

(*b*) Enclose the upper arm of the subject in the armlet and with the arm horizontal and at the level of the heart, place one finger on the radial pulse and raise the pressure in the instrument some 3 cm. above the point at which the pulse disappears.

(*c*) Release the pressure gradually and note carefully the

exact height of the mercury at the moment when the pulse returns at the wrist. This is the *maximum systolic* pressure.

(*d*) Still releasing the pressure slowly, note the mean pressure which allows the largest movement in the mercury. This is the *diastolic pressure.*

4. *Blood Pressure in Rabbit.—Demonstration of the Method of Recording this by the Mercurial Manometer* (Kymograph).

Demonstration of the effects upon the Arterial Pressure and upon Respiration of—

1. Nitrite of Amyl—inhalation.
2. Adrenalin—intravenous injection.
3. Section of one vagus.
4. Stimulation of the lower end of the cut vagus.
5. Section of other vagus.
6. Increase of CO_2 in air breathed.
7. Asphyxia.

II. Flow of Blood.

Study the circulation in a frog's foot under the microscope, and by means of an eye-piece micrometer try to measure the rate of blood-flow in the capillaries.

VI. RESPIRATION.

1. What changes take place in the chest during breathing? (*a*) With a tape, measure the circumference of the chest of a companion in full expiration and in full inspiration and record the result. (*b*) With the *cyrtometer* provided take a tracing of a section of the chest in expiration and in inspiration and compare them, measuring and recording the diameters.

(*c*) Now place the middle finger of the left hand flat on the sixth right intercostal space in front of the chest and strike it firmly with the middle finger of the right hand. Do this during expiration and during inspiration, and note any difference in the sound produced. The air-containing lung

yields a resonant note, the solid liver yields a dull note. Record your conclusion as to the vertical extent of the lung in expiration and in inspiration.

2. **What sounds are produced during breathing?** With a stethoscope listen (*a*) over the windpipe and (*b*) over the middle of the right side of the chest in the axillary line while the person breathes, and describe the sounds heard at each place, timing their relationship to inspiration and expiration.

3. **What is the rate of respiration?** Count the number of respirations in a person who has been and is sitting still, and again in the same person after taking violent exercise.

4. **Why do the lungs collapse when the thorax is opened?** Distend the rabbit's lungs given you by blowing into the trachea and then observe their elastic collapse. Measure the force of this with a water manometer.

5. **How to record the movements of respiration.**

(1) To record the movements of the air. Arrange a slow moving drum. Connect a recording tambour by means of a piece of rubber tubing with a short piece of glass tube. Insert the glass tube into one nostril, and breathe with the mouth closed, recording the movements of the lever. Now put a time record in seconds on the drum and measure the duration of inspiration and of expiration.

(2) To record the movement of the chest wall. Insert in the course of the rubber tube a glass T tube with a clamp. Connect the glass tube with a toy balloon, and place it under the waistcoat or a bandage round the chest, and slightly distend the balloon. Take a tracing.

These records should be taken with the subject sitting still.

6. **What is the influence of CO_2 on the respiration?**

(1) Examine the pulse (p. 50, 3). Run several times up and down stairs to increase the CO_2 in the blood, and again record the respiration from the nostril and examine the pulse.

(2) Breathe deeply and forcibly for about two minutes, so as to clear the CO_2 out of the blood. Then insert the tube

in the nostril, sit quietly, and have the respiratory movements recorded by another student who should also observe any change in the appearance of the face. Note any subjective phenomena. Examine the pulse.

7. **Demonstration of the influence of the vagus and of cutaneous nerves on the breathing of an anaesthetised rabbit.**

8. **What changes take place in the air breathed?**

(1) Breathe upon a piece of cool clean glass.

(2) Breathe out repeatedly through the vessel of lime water provided.

(3) Breathe out repeatedly through the weak solution of potassium permanganate provided.

(4) Light the candle in the bottle provided, and continue to breathe the air of the bottle through the tube attached.

Note your results and conclusions.

9. What changes take place in the blood in passing through the lungs? (See PRACTICAL CHEMICAL PHYSIOLOGY, Noël Paton and Cathcart, p. 19.)

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